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ORIGINAL PAPER

Development of mobile GIS system for forest resources second-class inventory

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Abstract: A special mobile GIS (Geographic Information System) system used for forest resources second-class inventory was developed on the basis of traditional forest resources inventory, remote sensing, GPS (Globe Positioning System) and embedded technology. Portable instrument, embedded development and the integration technology of RS (Remote Sensing), GIS and GPS are all used in this special mobile GIS system. Further, the system composition, key techniques, and current situation of the practical application in China were analyzed in the study. The results are important for applying modern high-tech for the planning and design of digital forest resources to improve the precision and efficiency of inventory and reduce the labor cost and financial investment.

Keywords: embedded development; pocket computer; mobile GIS; forest resources inventory

Introduction

Forest resources second-class inventory is known as forest resources planning and design inventory. Under the leadership of provincial (autonomous regions) forestry bureau, the nationwide forest resources inventory in China are carried out every ten years. There are 2.85×10^{8} second-class sample plots in the whole country. Regarding paper topographic maps, forest maps, remote sensing images or aerial photographs as hand charts, investigators hold a compass in hand, a large number of survey cards and a tie measurement rope at the waist for field survey in traditional investigation mode. The work demands the person with high professional skill and strong map interpretation ability (Chang et al. 2006). The positioning accuracy of compartment and subcompartment is low. During field subcompartment inventory, bad statuses often appear such as misjudging point, wrong area of subcompartment and compartment line starting from wrong point etc. Some errors exceed the limited error by more than 30%. Therefore, satisfied inventory results often can not be achieved because of some historical reasons, inconformity of map and field, and unclear boundary etc. in traditional investigation mode (Wang 2007).

There are large amounts of data processing works after finishing field survey in traditional method, including boundary digitization of compartment and subcompartment, data input of survey cards and office computing etc.. Generally, it takes half year in field investigation, half year in data processing work (Tang et al. 2009; Liu et al. 2009; Shi and Wang 2008). In traditional method, field work needs high-intensity labor force while with low accuracy. Data processing is trivial and boring, and human errors may appear at any moment.

In the past decade, with the quick development of microcomputer technology, RS, GIS, GPS and modern communication technology, the study based on microcomputer and integration technology of RS, GPS, GIS and modern communication technology has become the focus in the whole world (Liu et al. 2002; Zhao et al. 2002). As far as forest resources inventory in our country was concerned, hand-held GPS receiver was used in forest resource inventory fields from the end of the 20th century. Many organizations in forestry system bought lots of GPS receiver from 1997 to 2002, these GPS receivers were used for sample plot positioning and restoration. Although hand-held GPS receivers can only obtain geographic coordinates and implement simple navigation, compared with the traditional compass positioning, it is already a significant technology progress for forest resources inventory.

Since 2000, microcomputer equipments such as PDA (Personal Digital Assistant), plug-in GPS and Bluetooth GPS have come into being. Embedded platform (Embedded VC ++) and GIS technology have also been well developed. Many forestry science researchers paid close attention to mobile GIS development based on PDA (Zhang and Zhang 2008; TSOU 2004; Hardy 2002; Robert 2004). They plan to develop software system for forest resources inventory by highly integrating remote

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sensing, GIS, GPS and communication technology. The traditional mode of second-class forest resources inventory was improved. As shown in Fig. 1, the embedded GIS software was developed, and the GIS can run on microcomputer by using embedded platform (Embedded VC++). This software can show remote sensing images and vector maps on mobile device, positioning and determining the current position of users, and it can display them in the vector and grid map. Database of resources survey factors is embedded in it. Further, we can realize the digitization of field data collection and paperless inventory of forest resources, automatic mapping and warehousing. Eventually, the investigation precision and efficiency will be improved and labor intensity, saving human resources and funds will be reduced.

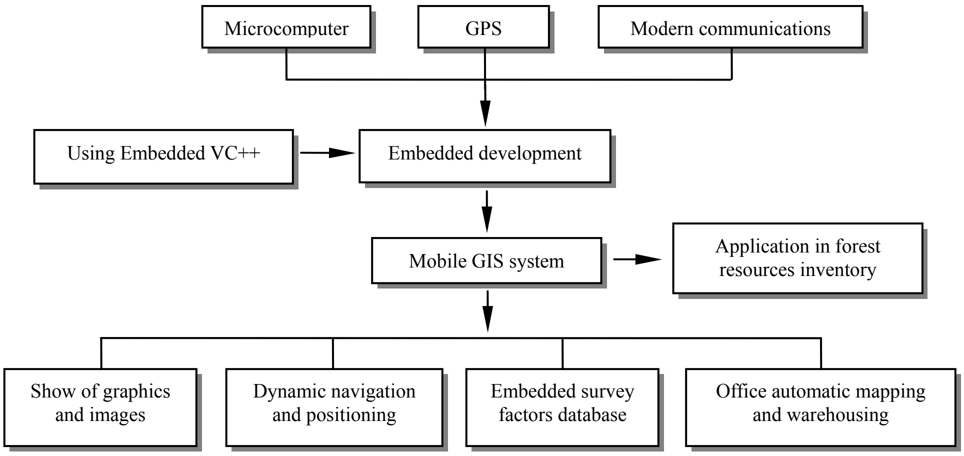

Fig. 1 Application concept of high-tech to forest resources inventory

The overall design and functions of the system

Embedded GIS software is developed by Embedded VC++, and operating system is Windows Mobile or WinCE. Hardware resource constraints must be overcome when we develop embedded GIS software in microcomputer. Most of the memory of the latest PDA at present in the market is 128 M, and its CPU (Central Processing Unit) frequency is usually 600M. There is no hard drive, only a SD (Secure Digital Memory Card) slot or CF (Compact Flash) slot. It is difficult to develop GIS software and load a large number of graphic and attribute data via limited hardware resources. Specific graphics and attribute data formats should be defined to improve the efficiency of data processing, and the compatibility and data sharing should be also taken into account.

The characteristics of forest resources second-class inventory in China are taken into consideration. Regarding paper topographic maps, remote sensing images, and forest map as base maps, the investigators interpret surface features, determine the location of compartment and subcompartment, and then divide compartment and subcompartment boundaries in the base map. The factor value of the survey properties is filled in via the investigation cards. And then, the field investigation was finished. The base geographic data include graphic data, image data and attribute data etc. in software system. The entire system is designed as Fig. 2.

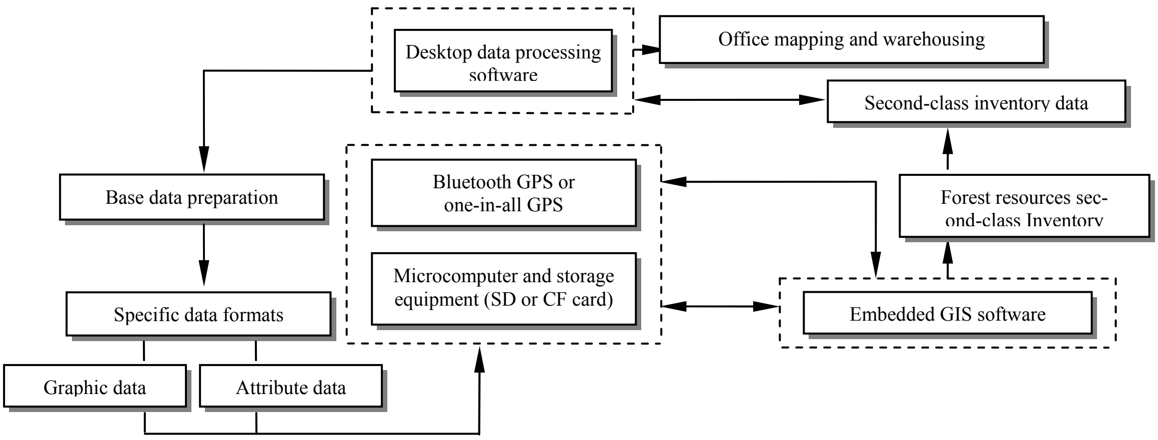

Fig. 2 The whole composition and data streams of the system

The entire system consists of portable hardware, embedded GIS software and desktop data-processing software as shown in the dashed box of Fig. 2. Portable hardware, including PDA and Bluetooth GPS, is mainly used to run the embedded GIS software, receive GPS satellite signal, and store graphic data, attribute data and field survey data.

Desktop data processing software is used to prepare graphics and attribute data, provide data dictionary for investigators to customize the survey attribute factors, realize the automatic mapping and warehousing of field investigation results, and conducted all kinds of calculations, inspection and statistical analysis etc..

Embedded GIS software should have the ability of loading graphics and attribute data. The data are processed by desktop data-processing software, GPS dynamic navigation positioning based on vector or raster maps, and the divisions and edit of compartment and subcompartment etc..

Core technologies and implementation

Graphics and image processing

Remote sensing images, which have a variety of spatial resolution, scanned topographic maps, forest maps (including bmp, tif, and jpg and other formats), vector maps such as ArcGIS's shp format and MapInfo's mif format data, are firstly processed by the desktop data processing software, then copied to the SD or CF memory card of the mobile device, finally loaded and quickly displayed by embedded GIS software. Embedded GIS software can automatically detect graphics file in the SD or CF card, and make a list. The user can choose one or more graphics file once according to their needs. If the raster image is registered, multiple graphic files loaded can automatically finish edge matching and creating thumbnails. Fig. 3 is graphic and image processing function module. Graphic and image processing function can solve the following key production issues:

(1) Load pieces of remote sensing images or scanned topographic maps at the same time. Multiple graphics projects can be prepared in a large area. The users can load the projects at any time according to their needs. Raster images are processed by desktop data processing software, and image data with 5−10 G can be stored in a 1 G memory card. Therefore, the forest resources second-class inventory can be carried out by the county.

(2) Investigating compartment and subcompartment can effectively overcome the limitations of limited graphics area. Compartment division and subcompartment division can deal with edge matching in traditional survey mode.

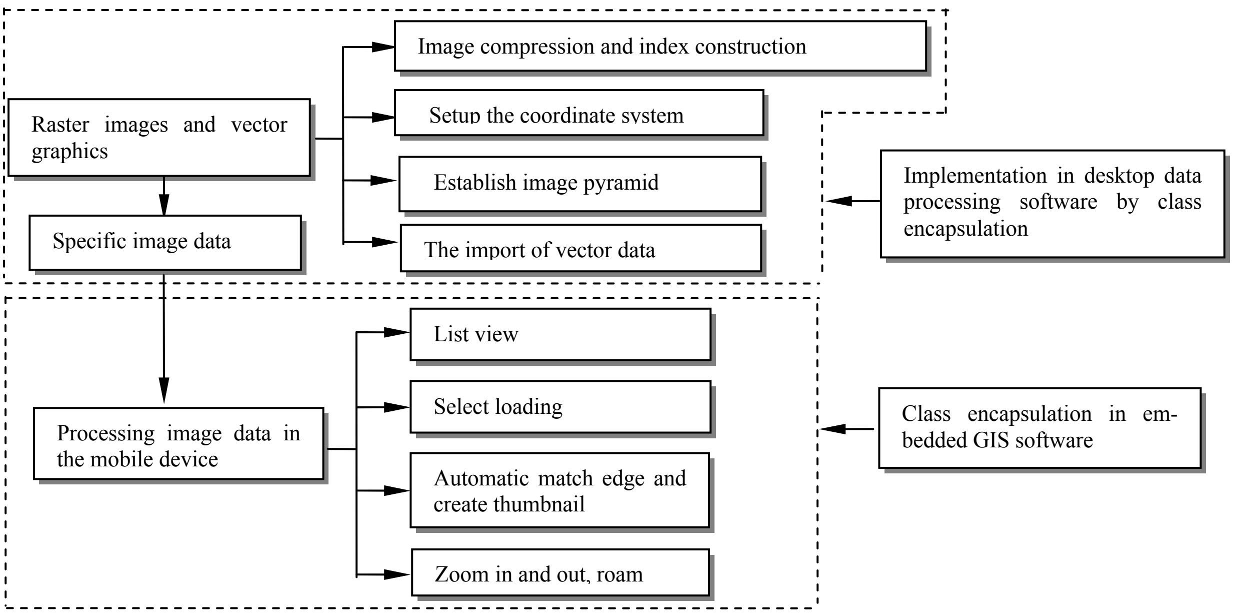

Fig. 3 The module of the vector and raster data processing

(3) Simultaneously, load remote sensing images, scanned topographic maps, vector maps, and forest maps in the same area. The various layers of the display can be switched and adjusted in real time according to users' needs, which is convenient and fast for forest resources second-class inventory.

(4) Raster image registration is made by geodetic coordinates or polygon coordinates. Embedded GIS software can load the registered images and images without registering. Fig. 4 (a) and (b) are the examples of raster image displays in the mobile device.

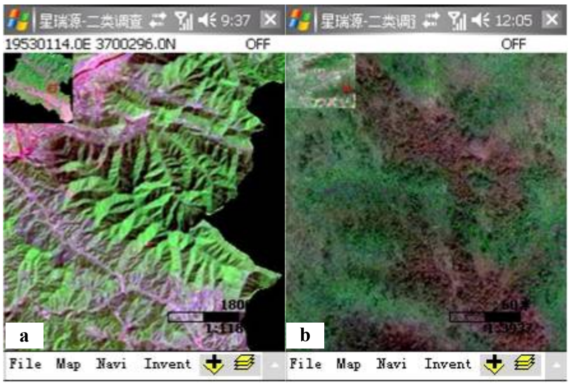

Fig. 4 Display of (a) TM remote sensing image and (b) IKONOS remote sensing image

Compartment and subcompartment division

Compartment and subcompartment division are completed by embedded GIS software. After loading the raster image which can be regard as a base map, vector layers such as point, line and polygon can be constructed or loaded, and the properties library information can be configured to these vector layers, subcompartment divisions of point and line and polygon. Then, the vector layers can be easily carried out in field. Subcompartment divisions can effectively deal with the following problems:

(1) Input mode setting of operation pen of mobile device, including stream input and click input. The so-called stream input continuously draws boundary just with pencil on paper map.

(2) When one subcompartment has one or several adjacent subcompartments, the software can automatically follow and capture the public boundary between these subcompartments.

(3) Hand-painted and the GPS measurement can be carried out at the same time.

(4) Subcompartment divisions can efficiently deal with subcompartment segmentation and merge, including graphics data processing and attribute data replication etc..

(5) Subcompartment divisions can carry out area adjustment for isolated islands, intersecting of line subcompartments and intersecting of line subcompartment and polygon subcompartment.

(6) Subcompartment divisions can make mixed drawing of line subcompartment and polygon subcompartment. In practice, investigators firstly decide the line boundaries of survey region, such as ridge lines, valley lines, rivers, roads and administrative boundaries, then decide the polygon subcompartment based on line boundaries.

(7) Subcompartment divisions can edit subcompartment, including increase of boundary points, removal of boundary points, cancellation of the wrong drawing, the movement of boundary points, and the movement of the whole subcompartment.

(8) Subcompartment divisions can fill in subcompartment attribute factors, including default settings of filled factor, real-time logic checks, calculation of species composition, calculation of volume, area adjustment.

(9) Subcompartment divisions can quickly retrieve subcompartment on mobile devices, including query from map to attribute and query from attribute to map.

(10) The efficient operation of large amounts of data, including the handling of subcompartment about 10000, the loading of raster images about 1G and more.

The above function modules can be achieved with the class encapsulation in embedded GIS software. The stream input of subcompartment division on remote sensing image is shown in Fig. 5(a). Automatic tracking and capture of public side of two subcompartments is shown in Fig. 5(b). Automatic tracking of public sides of multiple adjacent subcompartments is shown in Fig. 5(c). Subcompartment segmentation is shown in Fig. 5(d). Two subcompartments combining are shown in Fig. 5(e). The new subcompartment after merger is shown in Fig. 5(f). Mixed-drawing of line and polygon subcompartments are shown in Fig. 5(g) and Fig. 5(h). Fig. 5(i) is the query from attribute to map. Fig. 6 is the example of Angle Gauge.

Data dictionary customization of investigation attribute database

To quickly carry out compartment and subcompartment division, the conveniently input of subcompartment attribute information and corresponding logic checks and calculations are important. In the same province, investigate factors may have some differences in different areas (counties and cities), the investigators must be able to adjust and customize their own investigation factor database according to specific needs when differences of the investigation factor exist, and without modifying software source code. The system provides the data dictionary which can effectively deal with such situation. The data dictionary design function is shown in Fig. 7.

Office automatic mapping

After the field investigation, automatic mapping can be made in the room, and the attribute factors can be automatically warehoused. In view of the popularity of GIS software such as ArcGIS and MapInfo in the field of resource investigation in China, this system can automatically convert field data of forest resources second-class inventory to *. shp and *.mif format, and attribute factors can be converted into *. mdb, *. dbf and *. xls data format. Therefore, sharing data can be realized.

Application of research results

This mobile GIS system has been applied since 2004, and it has been adopted in many forest organizations such as the first and second Forest Inventory and Planning Institute of Heilongjiang Province, China Forest Inventory and Planning Institute of Heilongjiang Province, the State Forestry Administration Da Hinggan Mountains Forest Inventory and Planning Institute, Inner Mongolia second Forest Inventory and Planning Institute, Inner Mongolia Forestry Investigation and Planning Institute, Forest Inventory and Planning Institute of Gansu Province, Forest Inventory and Planning Institute of Fujian Province, Forest Inventory and Planning Institute of Jiangsu Province, and Xinjiang Forest Inventory and Planning Institute etc.. After five years application and perfection, this mobile GIS system can fully meet the needs of digital forest resources second-class inventory.

The system can produce good social and economic benefits.

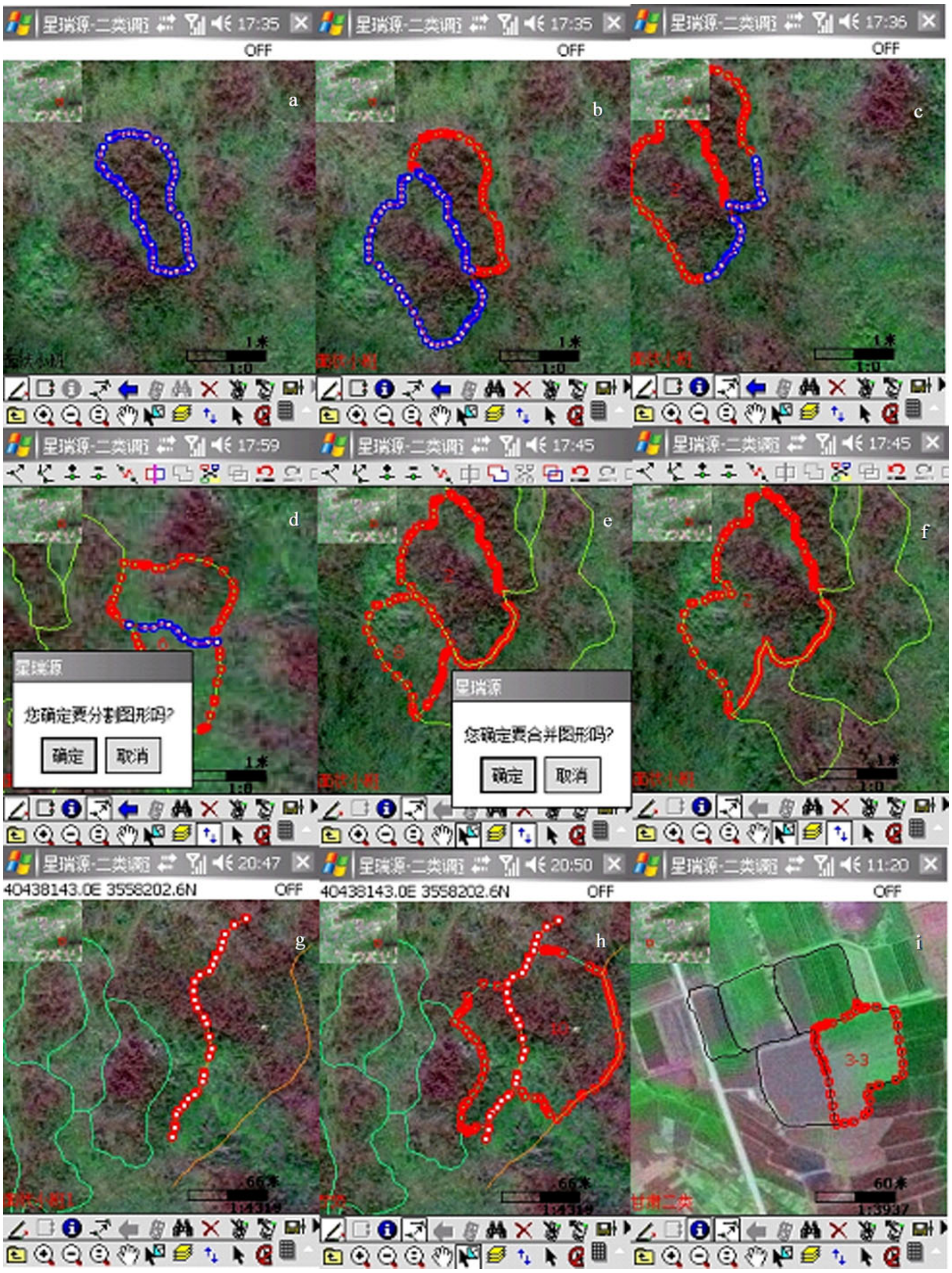

Fig. 5 Graphs from embedded GIS software: (a) Continuous drawing of subcompartment division; (b) Automatic tracking of public side of adjacent; (c) Automatic tracking of public sides of multi-adjacent subcompartments; (d) Subcompartments segmentation; (e) Subcompartment combining; (f) Merged subcompartment; (g) Drawing of line subcompartment; (h) Mixed drawing of the polygon and line subcompartment.

Conclusions

The embedded GIS software platform is completely constructed from the bottom with independent intellectual property rights. This system is equipped with the leading domestic and advanced world standard technology in many aspects such as the loading and quick display of huge raster data, stream subcompartment division, automatic tracking of public sides of adjacent subcompartments, subcompartment segmentation and merger, mixed treatment of the line and polygon subcompartments, and isolated island treatment etc..

The function of data dictionary effectively solves the influence of the difference of regional resource inventory, then the investi-

gators can customize inventory database in light of practical requirements.

Errors during the process of inventory can be found in real time by using the function of the automatic calculation and logic checkup to improve field inventory efficiency and reduce office calculation work.

The mobile GIS system can completely change the traditional mode of forest resources inventory based on paper topographic maps, remote sensing images and investigation cards. By using the map-based dynamic navigating and positioning and the embedded investigation factor database, this system can realize the digital division of the field compartment and subcompartment, office automatic mapping and warehousing. The system can improve the precision and efficiency of the investigation, realize the paperless second-class inventory of forest resources, integration of office and field work, and data sharing etc.. The research results are of great importance for promoting digital investigation of forest resources and forestry informationalization in China.

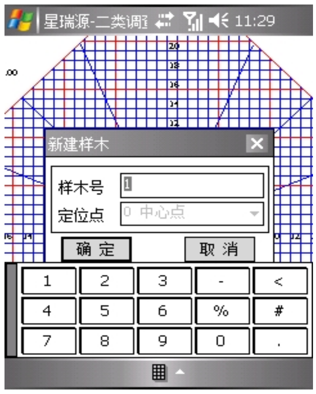

Fig. 6 Tree measurement with angle gauge

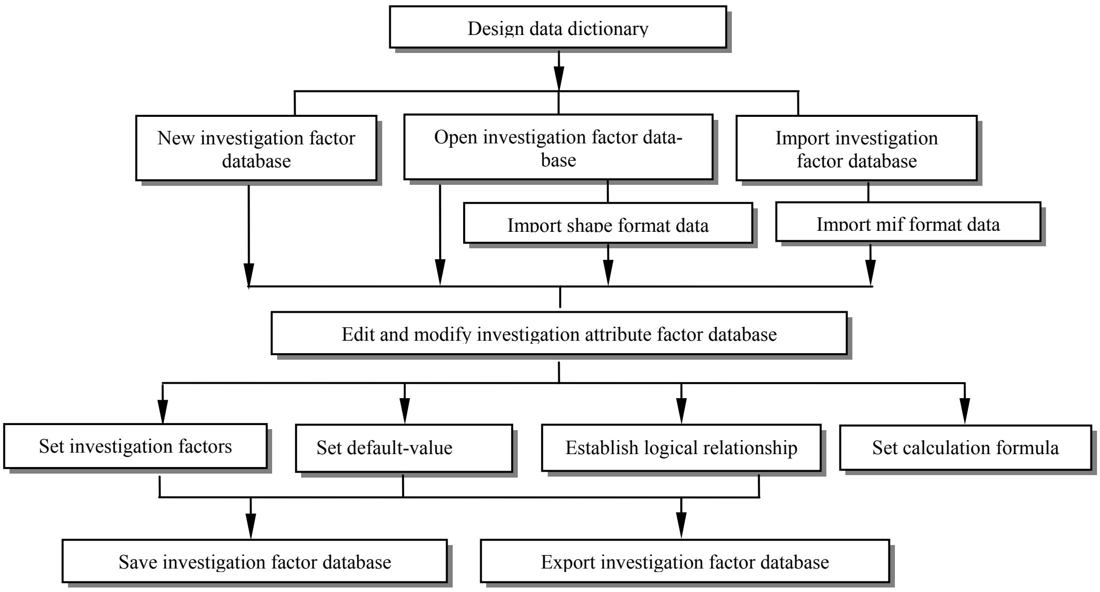

Fig. 7 The function of data dictionary

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